

considerable storm, then unexpectedly a few hundredths of an inch of precipitation to spoil an otherwise good forecast after the disturbance seemingly was all over. What is the exact nature of the terrain and what are the physical causes to produce such abnormalities? It is believed that the key to the answer may be summed up as follows: A high mountain barrier close to westward, but with a sizable gap to northwest for admittance of air currents. A gradually descending table-land from near this gap to southeastward, but with local air drainage considerably interfered with by numerous cross ridges. (The gap referred to is the comparatively low and narrow part of the Cascade Mountain platform in the vicinity of Snoqualmie Pass.)

With such a setting, the most pronounced adiabatic and radiational effects in the behavior of temperatures must be expected. It is the task of the forecaster, through continued application, to be able to estimate these effects. Variations in the maximum temperatures are uncommon and unimportant. In estimating minimum temperatures, the well-known hygrometric formula is used in connection with the evening weather map. The problem is to find the departure of the coming minimum above or below a median figure for dew point and humidity. Common types are: 1. Any pressure formation that will produce a north to south gradient, which, even weak, will cause steady, descending air movement at night with comparatively high temperature, while there may be no wind with lower temperatures in other districts. 2. The typical frost type is the weather map with indefinite gradient, or even strong southwest to northeast; then ideal conditions for uninterrupted radiation are provided, and the temperature fall is limited only by temperature of the dew point and time of sunrise. 3. But, let there be a south to north gradient, and a sluggish effect is noticeable, favorable for the development of cloud and higher temperatures. 4. With east to west gradient, cold air may be imported from the highlands of the Rockies and temperatures drop, even in the face, apparently, of a coming storm. Forecasting from the morning map, type and intensity which will produce the nighttime conditions have to be anticipated.

In the matter of precipitation, effect of the terrain seems to be even more pronounced. An increase in the annual total is noted as the Snoqualmie and Columbia River gaps are neared. The greater portion of the valley must get its precipitation through convection in a comparatively dry atmosphere or from admixture of the local atmosphere and a descending, drying current. As a rule, appreciable precipitation does not occur with a strong barometric gradient or even moderate general winds. The most common and favorable formation for precipitation is believed to be just after the center of the storm has begun to pass eastward, distance between the isobars widens out, and a certain amount of convection and mixing in a fairly moist atmosphere is possible.

One of the most remarkable peculiarities of the Yakima Valley weather is the variation of wind velocity with the seasons. The prevailing direction the year around of course, is northwest. During the winter months, December, January and February, when inland temperatures are low, there is no stimulation to the wind development of passing pressure formations. The absolute lack of local air drainage is most noticeable, the average hourly wind velocity at the Yakima Weather Bureau station being only two or three miles per hour. Smoke from local heating plants gathers over and in the city, conditions often rivaling those in the industrial centers of the east. With the coming of spring in March, however, the east to west temperature gradient is reversed. Each passing of a low trough is the signal for a rising northwest wind, with maximum generally in the afternoon and gradually dying down at night.

At intervals, winds develop in the spring season that are a temporary hazard to aviation. The pressure type is invariably an Alberta Low with trough to southward. The difficulty in forecasting these winds any satisfactory time interval in advance is due to the variations in intensity of the different Lows, a condition which is not always apparent on the weather map. Such winds often stir up dust storms of wide extent, interfering with visibility occasionally enough to obscure a landing field. The vertical limit of a dust storm, however, is rarely over 1,000 feet.

THE PASSING OF THE MIRAGE LOCALLY

By A. A. JUSTICE

[Weather Bureau Office, Dodge City, Kans., July 27, 1930]

Mr. Robert M. Wright, in Dodge City, the Cowboy Capital, pioneer plainsman, freighter over the Old Santa Fe Trail, and for more than a half century an observer of conditions in Kansas, Colorado, and New Mexico, paints a very good word picture of the mirage as he saw it in the days before extensive settlements had been made in this region by the white man. He tells how the prairies were changed from dreary wastes into scenes of enchanting beauty, how cities, castles, and fortresses suddenly sprang up in a land where no man dwelt, and how lakes and rivers of sparkling water shimmered ahead of the thirsty traveler enticing him from the beaten trails, on and on to his death. He ends with the following:

With the trail of the plow, followed by immigration and civilization, the wonderful mirage is a thing of the past. It is only now and then that one gets a glimpse of its beauties; its scenes of magnificence, far beyond any powers of description, I shall never see again.

That the mirage was of common occurrence during the period of settlement of the plains there can be little doubt. The frequency of its mention in the literature of the period

is convincing evidence of that. And then, too, we have the corroborative testimony of the older living residents.

And what of it to-day? Is it still to be seen as often and on the same grand scale as it was 30, 40, or 50 years ago? Unfortunately our records are meager. The Weather Bureau has never taken very particular notice of the mirage nor compiled any data as to its occurrence, either in years past or to-day. It is evident, therefore, that we can not say definitely whether or not the mirage is passing as Mr. Wright claims.

But curiosity impels the question as to what other people think about it; what is the experience of some other old-timers. The mirage is an interesting phenomenon and it played a prominent part in the early history of the plains. It was something new and strange to the early settlers and they wrote back and told their friends whom they had left behind about it. So its fame spread.

Stories of how the mirage lured the thirsty travelers from the beaten trails are not figments of the imagination in all cases. First-hand knowledge of such experiences is related by living pioneers. But as a rule the

experiences of the newcomers to the prairies were not of such a tragic nature. An instance will illustrate.

Mr. Ham Bell, one of the oldest living residents of Dodge City and of southwestern Kansas, tells of his introduction to the mirage. "I came to Kansas," said he, "in 1872, landing one night in Ellsworth. The next morning I engaged a hack driver to take me to Great Bend, a distance of 45 miles. The driver charged me \$45, a dollar a mile, for the trip, and he demanded payment in advance. The excuse for such an exorbitant price being the danger that would attend the crossing of a lake which could be seen in the distance and which he said his team would have to wade. The lake was only a mirage, but the rascally driver had my money before I found it out. The mirage is not seen to-day as it was then and people do not talk of it as they did in those days."

Commenting on the above, Mr. H. C. Bower, cooperative weather observer at Ellsworth, said: "The mirage is a rare occurrence in this part of the country nowadays. Not nearly so common as in years past."

A score or more of the older residents of Dodge City and southwestern Kansas were consulted by the writer. All were of one opinion—that the mirage is not now so common as it was in the early days, and that it does not occur on the same grand scale now as it once did.

Dr. O. H. Simpson, dentist, said:

When I came to Dodge City in the early eighties, mirages were very common in this part of the country. In 1884 I drove over from Wichita with my bride and there were mirages all the way. I recall joking the wife about the rides which we would take on those "lakes." But it is quite different to-day. One can make the trip from Wichita here in the most favorable weather and perhaps never see a mirage, except the small ones in the level stretches of paved roads.

Dr. Claude E. McCarty, the first white child born in Dodge City, and, in the days of the Signal Corps, a civilian assistant at the Dodge City weather station, said:

I am sure that there are not so many mirages to-day as there once was and they are not so big either. Why, it's been years and years since I have seen a mirage. Before the prairies were broken up one could not drive out in the country around Dodge City without seeing a mirage if the weather was favorable.

Others could be quoted without end. In talking with some people who have come to this country within the last 10 or 15 years some were found who had never seen a mirage and some of these people, maybe all of them, have automobiles and take occasional rides out into the country. The writer has been stationed here for the last 10 years and during that time has observed about three mirages. These were "loomings" on the southern horizon and were seen from the Weather Bureau building. They were insignificant, however, and perhaps would not have been noticed by the average person.

The country in the immediate vicinity of Dodge City is more or less broken and for that reason is not favorable for the appearance of the mirage. But away from the city a few miles there begin level stretches which extend long distances, and here the mirage might be seen on any warm sunny day provided other conditions were favorable, but evidently other conditions are not often favorable for it is rarely that the mirage is seen here.

Thirty years ago the writer spent a year on the Staked Plains of Texas. At that time and that region the mirage was exceedingly common. It was to be seen everywhere, if the sun shone and the weather was warm. It was very deceptive, for in many instances one could not tell for sure if he were looking at a real lake or a mirage. When the weather was favorable, the mirage usually made its first appearance around 9 o'clock in the morning and continued till about 4 in the afternoon. The "lakes"

would usually appear to come as close as a half mile to the observer, varying with the observer's distance above the ground. By lowering the eyes to near the ground the mirage would appear to come within a hundred yards of the observer.

There were two distinct kinds of mirages. The "lakes" were by far the most common. These would be best when the sky was clear, but sometimes they could be seen even with an almost completely overcast sky. The wind did not prevent their formation, but would affect the illusory lake surface just as it would the surface of real water, ruffling it into small waves.

On very rare occasions, when conditions were just right, the manifestation technically known as "looming" would appear. This would develop on still, clear mornings when the ground surface had cooled off decidedly during the night, thus forming a layer of relatively cool, dense air next the surface of the ground. This mirage could as a rule be first seen with the advent of dawn. Distant landscapes would be elevated above the ordinary horizon, sometimes as much as three or more degrees. Distant objects, sometimes including towns and ranch houses, could be seen distinctly many miles away. Sometimes the elevated landscape would be right side up and sometimes upside down, such an effect being known as mirage.

After the sun had risen sufficiently to begin warming the surface of the ground there would appear a streak of sky along and above the ordinary horizon. The observer could then see a long streak of landscape, like a low-lying cloud, cut away from the earth by a gradually widening streak of skyline, the latter looking much like a streak of water. The streak of elevated landscape would grow narrower and narrower until at last it would disappear like a cloud in the sky.

Whether or not the mirages of the Staked Plains occur to-day as frequently and on the same scale as in years past remains a question, though the claim is made that the advent of the plow has had the same effect in that region as it has in others.

Mirage is caused by the refraction of light rays as they pass through layers of air of different densities. These layers of air of different densities are produced either by the excessive heating of the ground surface by the sun's rays in the daytime, which produces a layer of air next the ground of a higher temperature and of less density than the air layer immediately above; or by the excessive cooling of the ground surface by radiation at night which produces next the ground a layer of air of lower temperature and greater density than the air layer immediately above it.

In the first instance, rays of light, coming from the sky, strike the eye of the observer as coming from some point on the ground. This is because they are bent out of their course as they enter layers of air of different density. Thus a patch of sky is seen on the ground and is changed by the fancy of the observer into a lake of water.

In the second instance rays of light coming from objects beyond the horizon are bent in such a way as to strike the eye of the observer as coming from a point in the sky. Thus the observer sees the distant landscape up in the sky. This is the phenomenon known as "looming."

Mirages are commonly associated with water surfaces where a light wind from the land brings air of a different temperature from that over the water, also with deserts and sandy plains, for in such regions the ground heats up more quickly under the sun's rays and at night cools off more quickly than it does where vegetation partly or wholly covers the ground. It is obvious that the denser

the vegetable covering the smaller and slower will be the temperature changes of the ground surface and the less probability will there be of the appearance of the mirage. This is the basis of the argument that the turning of the prairies into farms has affected the frequency of the appearance of the mirage, for during the summer season, the time when mirages are most frequent, the crop covering is much more dense than that of the prairie grass covering. It is claimed that for a year or two following the great fires which occasionally swept the prairies in the early days, the mirage was unusually common. The fires burned the dry, dead vegetation which accumulated on the ground with the years and for several months thereafter there was more bare ground exposed to the

sun's rays, etc., thus making the conditions more favorable for the formation of the mirage.

While such evidence as we have does not *prove* nor even *indicate* that the mirage has entirely disappeared from any extensive region, it does lend strong support to the statement of Mr. Wright that much of the beauty and glory of the mirage has vanished. That the phenomenon is occasionally seen around Dodge City and in other parts of southwest Kansas we have the positive statements of eye witnesses, many of them, that it is not seen nearly so often to-day as formerly is the positive assertion of many eye witnesses, with none, so far as the writer knows, claiming the contrary.

SIMPLIFIED RAIN-INTENSITY FORMULAS

By C. E. GRUNSKY

[57 Post Street, San Francisco, Calif., October, 1930]

The account given by George V. Fish, United States Weather Bureau Office, Fla., in the MONTHLY WEATHER REVIEW, June, 1930, of a record rainfall at Miami from May 29 to June 2, inclusive, prompts the submission of formulas for the determination of probable maximum rain intensity during time periods of any length (less than a year) when the maximum rain rates during one or more storms of the extreme type are known.

It has been customary, heretofore, in such formulas to express time in minutes and the rain intensity in inches per hour. The formulas will take on a more convenient form if the duration of the rain be expressed in hours instead of in minutes.

No one has yet suggested a simple, single formula for rain intensity, satisfactorily applicable to such periods as a small fraction of an hour, an hour, a day, a week, a month, and an entire season. It is believed that the desired near approach to actual fact and a wide range of the time period can be obtained with the two formulas below noted. It is well known that for short periods of time the summation or mass curve of rainfall of maximum intensity has a shape closely approximating a parabola. The elements of a parabola, however, which will fit conditions of rain intensity for periods up to 24 or even 48 hours, indicate too much rain for materially longer periods. It is this fact which has led to the suggestion of two very simple formulas, one for rainstorms of relatively short and the other for storms of long duration. It is hoped that these formulas may prove helpful in determining from measured heavy rain rates the probable maximum rainfall in other than the observed time period.

Let I_t represent the maximum average rate of rainfall, expressed in inches per hour, during any definite time period t .

Let t represent the time, expressed in hours, during which rain falls with the average intensity I .

Let C represent a coefficient which is to be ascertained for any locality from records of rainfall of extreme intensity.

Let R represent the maximum rainfall in one hour, expressed in inches.

Let R_t represent the total rainfall from the beginning of a rain storm of maximum intensity, during the t hours of its duration.

The probable maximum intensity of rainfall during various periods of time can then be determined with the aid of the formulas:

$$I_t = \frac{C}{\sqrt{t}} \text{ when } t \text{ is less than 64 hours.} \quad (1)$$

$$I_t = \frac{2C}{\sqrt{t^3}} = \frac{2C}{t^{3/2}} \text{ when } t \text{ is greater than 64 hours.} \quad (2)$$

These formulas in this simple form and their combination, which results in a continuous curved line, with a single negligible angle, will be found particularly helpful in approximating maximum rainfall for periods which do not differ too widely from the period of observed heavy rainfall which determines the value of the coefficient C .

It follows from (1) and (2) that—

$$R_t = \frac{C}{\sqrt{t}} t = C\sqrt{t} \text{ when } t \text{ is less than 64 hours.} \quad (3)$$

$$R_t = \frac{2C}{t^{3/2}} t = 2C\sqrt{t} \text{ when } t \text{ is greater than 64 hours.} \quad (4)$$

Moreover the coefficient C will be equal to the maximum rain in one hour, because for $t=1$ it will be found from equations (1) and (3) that

$$I_1 = C = R_1$$

Rain at Miami, Fla., May 29 to June 2, 1930, Compared with Computed Maxima

Period	Observed rainfall		Computed by formula		Remarks
	Intensity per hour	Amount	Maximum intensity per hour	Maximum amount	
Hours	Inches	Inches	Inches	Inches	
0.167			6.1	1.02	10 minutes.
.50			3.5	1.77	30 minutes.
1	1.87	1.87	2.5	2.50	
2	1.54	2.07	1.77	3.54	
3			1.44	4.33	
4	1.10	4.39	1.25	5.00	
5	.80	4.53	1.12	5.59	By the formula.
6			1.02	6.13	$R_t = 2.5\sqrt{t}$
12			.94	8.65	
24	.38	9.36	.51	12.25	
44	.375	16.49	.378	16.60	
48			.360	17.3	
72			.296	20.6	
96			.242	23.2	
120	.161	19.28	.205	24.6	By the formula.
240			.108	26	$R_t = 5\sqrt{t}$
545	.061	33.16	.075	41	
720			.062	45	
1,440			.0395	57	Duration 1 month.
8,640			.0119	103	1 year.

¹ This includes a period of 49 consecutive hours on May 27, 28, and 29 after the beginning of the storm, in which no rain fell.